Early Journal Content on JSTOR, Free to Anyone in the World

This article is one of nearly 500,000 scholarly works digitized and made freely available to everyone in the world by JSTOR.

Known as the Early Journal Content, this set of works include research articles, news, letters, and other writings published in more than 200 of the oldest leading academic journals. The works date from the mid-seventeenth to the early twentieth centuries.

We encourage people to read and share the Early Journal Content openly and to tell others that this resource exists. People may post this content online or redistribute in any way for non-commercial purposes.

Read more about Early Journal Content at http://about.jstor.org/participate-jstor/individuals/early-journal-content.

JSTOR is a digital library of academic journals, books, and primary source objects. JSTOR helps people discover, use, and build upon a wide range of content through a powerful research and teaching platform, and preserves this content for future generations. JSTOR is part of ITHAKA, a not-for-profit organization that also includes Ithaka S+R and Portico. For more information about JSTOR, please contact support@jstor.org.

MINOR TIME DIVISIONS OF THE ICE AGE.

By Warren Upham.

The following study, forming the conclusion of Part VI in the Twenty-third (1894) Annual Report of the Minnesota Geological Survey, may be regarded as a continuation or supplement of my paper, on the periods of the Quaternary era, given in the American Naturalist last December. It seems to supply a compromise between the doctrine of unity of the Glacial period as held by Dana, Wright, and others, and the alternative doctrine of its duality or greater complexity as held, among American glacialists, by Chamberlin, Salisbury, McGee, and others. Unity or continuity of our Plistocene glaciation, with moderate fluctuations of the ice margin, appears to the present writer the more acceptable view and expression, when the whole period and the whole drift-bearing area are considered. This time was long as measured by centuries or thousands of years, but was in a geologic sense brief as compared with all other geologic periods or epochs, excepting only the shorter, unfinished Recent or Present period.

Seeking to subdivide the Ice age with reference to its dynamic causes and secular fluctuations in climatic conditions, we find, first, a long epoch of general snow and ice accumulation. In its early part the growth of the ice-sheet was interrupted, at least locally and temporarily, by moderate oscillations of its boundary, as shown by layers of lignite between deposits of till observed by Dr. Robert Bell on branches of the Moose and Albany rivers tributary to the southwest side of James bay.[1] Later, after the ice-sheet attained its maximum stage in the Mississippi basin, reaching south to northeastern Kansas, central Missouri and southern Illinois, this epoch included a long interval of extensive retreat of that part of the ice-sheet, followed by renewal of its growth until it again reached far south toward its former limits. This part of the Ice age is well denominated, from its envelopment of the land by ice-sheets, the Glacial epoch. Its chief cause I think to have been uplifts of the glaciated regions thousands of feet above their present height.

---

[1] Geol. Survey of Canada, Report of Progress for 1877–78, p. 4 C; and Annual Report, new series, vol. ii, 1886, p. 38 G.

Forest beds and other fossiliferous deposits of the interglacial stage in this epoch are found frequently, and on some large tracts almost continuously, occurring between deposits of the till or glacial drift penetrated by wells, from southeastern Ohio, through Indiana and Illinois, to northeastern Iowa and to Mower county in southern Minnesota.[2] Less frequent, but still sometimes occupying considerable tracts as shown by several wells near together, these interglacial beds are recorded by my notes of wells in Lyon, Renville, and McLeod counties, Minn., 60 to 90 miles north from the south line of this state. More rare instances of their observation are noted as far north as in Mitchell township, Wilkin county, and Barnesville in the south edge of Clay county, Minn.; and these most northern localities are situated within the area of the glacial lake Agassiz, respectively about 100 feet and 75 feet below its highest and earliest or Herman beach. If the altitude and slopes of the land had been then the same as now, an interglacial lake, held by the barrier of the receding ice-sheet, must have forbidden the growth of forests or formation of swamp deposits there, until the outlet was deeply eroded or much farther glacial recession permitted that lake to be drained away northward. Under those conditions an interglacial forest at Barnesville would imply probably three to six times more glacial melting and recession than otherwise would suffice to account for the most northern of these observed interglacial deposits. It therefore seems to me more likely that during this glacial retreat the present basin of the Red river of the North, which was later occupied by lake Agassiz, had a considerably greater altitude than now, retaining a part, probably a large part, of its preglacial elevation, and that it was thus a land surface with southward descent and free drainage along the Minnesota river valley to the Mississippi. The recession of the ice-sheet, before its renewed growth, may then have reached only to the southern part of the Red river valley, instead of the great farther distance to Hudson bay, which I formerly supposed in writing of these interglacial beds in Minnesota.[3]

---

[2] Charles Whittlesey, Smithsonian Contributions, No. 197, in vol. xv, 1864, pp. 13-15.

J. S. Newberry, Geology of Ohio, vol. ii, 1874, pp. 30–33.

G. F. Wright, The Ice Age in North America, 1889, pp. 475–496.

Frank Leverett, Proc. Boston Soc. Nat. Hist., vol. xxiv, pp. 455–459, Jan. 1, 1890; Journal of Geology, vol. i, pp. 129–146, with map, Feb.-March, 1893.

W J McGee, Eleventh An. Rep., U. S. Geol. Survey, for 1889–'90, Part I, pp. 486–496.

N. H. Winchell, Proc. A. A. A. S., vol. xxiv, for 1875, Part II, pp. 43-56; Geology of Minnesota, Final Report, vol. i, 1884, pp. 313, 363, 390.

The erosion of numerous and large interglacial stream courses in the early drift sheet of southern Minnesota and northern Iowa, including the Minnesota river valley and its continuation past Brown's Valley and above the bed of lake Traverse, channeled then apparently about 50 feet (or more) below the general surface of the adjoining country to the level of the Herman beach of lake Agassiz,[4] finds full explanation in this retreat of the ice-sheet to the vicinity of Mitchell and Barnesville, 200 to 250 miles inward from its farthest limits in North Dakota and on the northern boundaries of the Wisconsin driftless area, but 500 miles north from its limits in Kansas and Missouri.

During the ensuing stage of its renewed accumulation and growth, the ice-sheet reached from Barnesville about 200 miles westward into North Dakota, an equal distance eastward into northwestern Wisconsin and southeastern Minnesota, and some 350 miles or more south-southeastward in Iowa. Not only were the interglacial forest beds thus covered, but a marginal moraine, which had been formed probably during a slight pause or readvance interrupting the later part of the intermediate glacial retreat, was likewise buried and is now indicated by exceptionally abundant boulders in a stratum of the drift

[3] Geology of Minn., Final Report, vol. i, 1884, pp. 402, 406, 466, 479–485, 507, 511, 552, 580, 581, 585–6, 609, 625; vol. ii, 1888, pp. 138, 186, 187, 199, 456, 529, 555, 662, 668.

[4] Proc. A. A. A. S., vol. xxxii, for 1883, pp. 222–227. Geology of Minn., vol. i, pp. 479–485, 507, 580; vol. ii, 134, 172, 216, 519–525.

shown in the bluffs of the upper part of the Minnesota river valley and by its tributaries, overspread by 25 to 50 feet of the later deposits of till.[5]

The two stages of growth of the ice-sheet may have been due, aside from their principal dependence on the high elevation of the land, to the climatic effects of the last two passages in the precession of the equinoxes, with accompanying nutation, bringing the winters of the northern hemisphere in aphelion about 30,000 years ago and again about 10,000 years ago. The intermediate time of the earth's northern winters in perihelion would be the stage of great retreat of the ice margin in the upper Mississippi region; but eastward, from Ohio to the Atlantic coast, there appears to have been little glacial oscillation.[6] This explanation accords with Prof. N. H. Winchell's computations from the rate of recession of the falls of St. Anthony for the Postglacial or Recent period,[7] and with his estimate of the duration of the interglacial stage from the now buried channel which appears to have been then eroded by the Mississippi river a few miles west of the present gorge below these falls.[8]

The chief cause of the Ice age is here thought to have been a high epeirogenic uplift; but the very noteworthy subdivision of the Glacial epoch in the upper Mississippi basin is ascribed to climatic conditions resulting from the same astronomic cycle of 21,000 years which Croll supposed to have been efficient, during the remote time of maximum eccentricity of the earth's orbit, to produce alternating glacial and interglacial epochs. Wallace, in his discussion of this subject in "Island Life," thinks that great altitude of the glaciated countries coincided with the last stage of maximum eccentricity, from 240,000 to 80,000 years ago, to cause the Ice age, altitude and eccentricity being thought perhaps of nearly equal influence. The view here presented looks on the Glacial period as occurring in a much later time of low eccentricity, and for its causation regards altitude as far more efficient than any astronomic conditions. The effects of varying astronomic conditions have been recently considered by Dr George F. Becker,[9] who thinks, altogether differently from Croll, Geikie, and Ball, that the combination of minimum eccentricity of the earth's orbit and maximum obliquity of the ecliptic is most favorable for snow and ice accumulation; and he states that these conditions have existed within the past 40,000 years, until 8,000 years ago, but he apparently would attribute a larger share of the causes of glaciation to geographic conditions, as land elevation. In Europe a very remarkable parallelism of the history of the Ice age with that in America[10] indicates dependence on similar causes, chiefly geographic, as epeirogenic movements, with changes of ocean currents, and subordinately astronomic.

---

[5] Geology of Minn., vol. i, p. 626.

[6] J. D. Dana, Am. Jour. Sci., III, vol. xlvi, pp. 327–330, Nov., 1893.

[7] Geol. and Nat. Hist. Survey of Minnesota, Fifth An. Rep., for 1876, pp. 175–189; Final Report, vol. ii, 1888, pp. 313-341, with fifteen plates (views showing recent changes of the falls of St. Anthony, and maps). Quart. Jour. Geol. Soc., London, vol. xxxiv, 1878, pp. 886--901.

[8] Am. Geologist, vol. x, pp. 69–80, with three plates (sections and a map), August, 1892.

If the Glacial period extended through 30,000 or 50,000 years, depending principally on epeirogenic uplifts and in less degree on the cycles of precession of the equinoxes, it would agree well with Geikie's and Chamberlin's complex history of wavering glaciation, and also with its essential geologic unity and brevity which have been insisted on by Dana, Wright, Hitchcock, Lamplugh, Kendall, Falsan, Holst, Nickitin, and other glacialists. To my mind the diversity and the unity of this period seem like the opposite gold and silver sides of the proverbial shield, concerning which two knights, each having seen only one side, valiantly contended.

Widely extended depression of the ice-burdened land, until mostly it had somewhat less altitude than now, initiated the comparatively short final epoch of the Glacial period. Temperate and warm climatic conditions on the ice border, nearly as now on the same latitudes, then melted away the ice rapidly; its chief stage of loess deposition attended the early part of this glacial retreat; the partially unburdened land began to rise by a moderate uplift, approximately proportional to the glacial melting and nearly keeping pace with it;[11] and conspicuous belts of morainic drift were amassed whenever the steep waning ice-front slackened its departure, or halted, or for any short time reädvanced. The general but fluctuating retreat of the ice-sheet at length uncovered all the country and constituted the closing or Champlain epoch of the Ice age, so named from the marine beds of that time overlying the till in the basin of lake Champlain and along the St. Lawrence and Ottawa valleys, by which the vertical extent of the subsidence terminating the Glacial period and of the succeeding reëlevation is measured.

---

[9] Am. Jour. Sci., III, vol. xlviii, pp. 95–113, Aug., 1893.

[10] James Geikie, The Great Ice Age, three editions, 1873, 1877, and 1894, notably pp. 774, 775, in the third edition; Journal of Geology, vol. ii, p. 739, Oct.-Nov., 1894; Am. Geologist, vol. xv, p. 54, Jan., 1895.

Adopting the helpful new nomenclature proposed by Chamberlin,[12] we may provisionally formulate the minor time divisions of the Glacial and Champlain epochs as follows. The order of this table, as of the former more comprehensive one on page 988 of the last December AMERICAN NATURALIST, is stratigraphic, so that for the advancing sequence in time it should be read upward.

NOTE.—If we seek to compare this table with the Glacial series in Europe, it should be remarked that in the Alps there were three chief stages of growth of the glaciers far beyond their present limits, the second being the maximum advance, doubtless contemporaneous, as shown by Geikie, with the maximum extension of the ice-sheet upon northern Europe. The first glacial stage of the Alps, which also appears to have left traces in southern Sweden not wholly obliterated by the next and greater glaciation, may be represented in America by the till beneath the interglacial lignite in the basin of James bay, and these may belong to the time of northern winters in aphelion some 50,000 years ago. The second, third, and fourth glacial stages of the European Ice age, as tabulated by Geikie, are then seen to be wholly analogous in characteristics of ice extension and drift deposition, and they were probably also time equivalents, respectively, with the Kansan, Iowa, and Wisconsin stages in the United States and Canada. In each continent the interglacial time between the Kansan and Iowan stages had great subaërial erosion because of the continuing high elevation of the land; and the latest or moraine-forming stage of the glaciation seems, alike in Europe and America, to have belonged to the mainly rapid but fluctuating final retreat of the ice, showing, as I think, that each ice-sheet had in its lower part much englacial drift.

---

[11] Journal of Geology, vol. ii, pp. 383--395, May–June, 1894.

[12] In two chapters (pages 724–775, with maps forming plates xiv and xv) of J. Geikie's "The Great Ice Age," third edition, 1894, Prof. T. C. Chamberlin proposes a chronologic classification of the North American drift under three formations, named in the order of their age, beginning with the earliest, the Kansan, East Iowan, and East Wisconsin formations.

Epochs and Stages of the Glacial period.

CHAMPLAIN EPOCH (Land depression; disappearance of the ice-sheet; partial reëlevation of the land.)	WISCONSIN STAGE . . . (Progressing reëlevation.)	Moderate reëlevation of the land, advancing as a permanent wave from south to northeast; continued retreat of the ice along most of its extent, but its maximum advance in southern New England, with fluctuations and the formation of prominent moraines; great glacial lakes on the northern borders of the United States; slight glacial oscillations, with temperate climate nearly as now, at Toronto and Scarboro', Ont.; the sea finally admitted to the St. Lawrence, Champlain, and Ottawa valleys; uplift to the present height completed soon after the departure of the ice. (The great Baltic glacier, and European marginal moraines.)
	CHAMPLAIN SUBSIDENCE	Depression of the ice-covered area from its high Glacial elevation; retreat of the ice from its former Iowan limits; abundant deposition of loess.
GLACIAL EPOCH (Ice accumulation, due to the culmination of the Lafayette epeirogenic uplift.)	IOWAN STAGE	Renewed ice accumulation, covering the forest beds and extending south nearly to its early boundary. (Third European glacial stage.)
	INTERGLACIAL STAGE .	Extensive glacial recession in the upper part of the Mississippi basin; cool temperate climate and coniferous forests up to the waning ice border; much erosion of the early drift.
	KANSAN STAGE	Maximum extent of the ice-sheet in the interior of North America, and also eastward in northern New Jersey. (Maximum glaciation in Europe.)
	UNDETERMINED STAGES of fluctuation in the general growth of the ice-sheet.	Including an early glacial recession and reädvance in the region of the Moose and Albany rivers. (First glacial stage in the Alps.)